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FIELD CHLOROPHYLL MEASUREMENTS FOR EVALUATION OF CORN NITROGEN STATUS[1]

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ABSTRACT: An experiment was conducted on Norfolk sandy loam soil (Fine-loamy, siliceous, thermic Typic Kandiudults) during two years to determine the feasibility of using field chlorophyll measurements for evaluation of corn (*Zea mays* L.) N status. Nitrogen was applied at rates of 56, 112, 168, 224, 280 and 336 kg ha^{-1} to establish a range of corn chlorophyll levels, tissue N concentrations, and grain yields. At the V10 and midsilk stages of growth, field chlorophyll measurements were taken with a hand-held chlorophyll meter (SPAD-502 Chlorophyll Meter, Minolta Camera Co., Ltd., Japan)[3] and tissue N was determined. A typical curvilinear grain yield response to N fertilizer was observed both years; maximum agronomic yields were obtained with 227 and 242 kg N ha^{-1}, respectively, in 1990 and 1991. Tissue N concentrations at V10 and midsilk were a good predictor of grain yield. Field chlorophyll measurements were highly correlated with tissue N concentrations at both growth stages during both years of the study. Field chlorophyll measurements had excellent grain yield prediction capabilities, even at V10, which shows promise for utilization of this tool for in-season N recommendations. However, further calibration of field chlorophyll measurements will be required prior to routine use for corn N recommendation purposes.

INTRODUCTION

Prediction of N requirements is necessary for efficient utilization of fertilizer N and protection of ground and surface waters against contamination. Soil tests for these purposes have been used successfully in regions of low rainfall, such as the western U.S. where minimal NO_3 leaching occurs. Unfortunately, no reliable soil test has been developed for prediction of crop N needs in the humid Southeast (4). However, recent research (5) indicates that pre-sidedress soil NO_3-N tests may allow prediction of supplemental N needs for corn in the humid regions of the midwestern and northeastern U.S., and this tool may be useful in the humid Southeast. Tissue tests have shown promise for N need prediction, but time required for sampling and laboratory analysis may disallow timely producer response to crop N deficiencies.

Leaf chlorophyll, which is directly related to leaf N concentration (6), may serve as a useful index of leaf N concentrations, and, thus, aid in prediction of N requirement for crops. Currently, a nondestructive, hand-held meter is available for measurement of green color intensity in crop leaves (SPAD-502 Chlorophyll Meter, Minolta Camera Co., Ltd., Japan), which is directly related to leaf chlorophyll content (7). The meter is lightweight (225 g), is powered by two AA alkaline batteries, has a 2-second interval between measurements, and can store up to 30 measurements. Operationally, measurement of leaf color is accomplished by inserting a leaf blade into the head of the SPAD-502 Chlorophyll Meter (Fig. 1). The light source is two light-emitting diodes, and the receptor is a silicon photodiode.

The principle of measurement, developed by Inada (8), is based on the difference in light attenuation at wavelengths 430 and 750 nm. The 430 nm wavelength is a spectral transmittance peak for both chlorophyll a and b, while the 750 nm wavelength is in the near-infrared region, where no transmittance occurs. From the difference in light attenuation, a numerical SPAD (Soil Plant Analysis Development) unit, ranging from 0 to 80, is calculated by the microprocessor in the SPAD-502 Chlorophyll Meter.

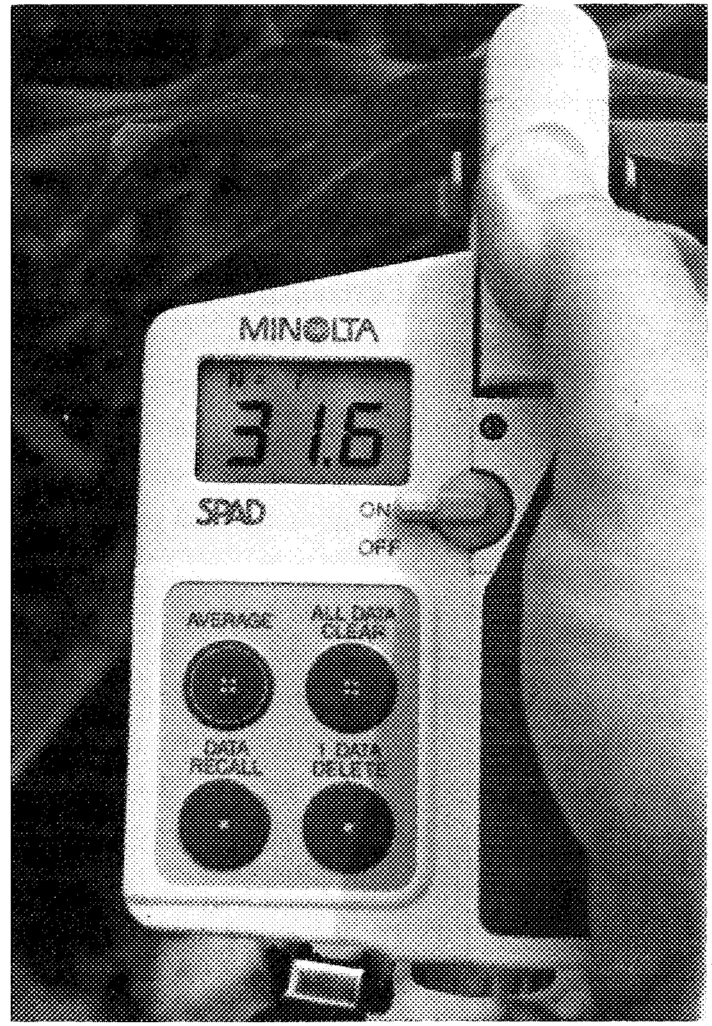

FIGURE 1. Measurement of Leaf Green Color Intensity with the SPAD-502 Chlorophyll Meter.

Chlorophyll meters have been used successfully by researchers in Japan for prediction of rice (*Oryza sativa* L.) N requirements (6, 7, 9). However, Takebe and Motomatsu (10) had less success in evaluating the N status of corn with field chlorophyll measurements. Currently, several studies concerned with utilization of field chlorophyll measurements for prediction of corn needs are being conducted in the U.S. (11, 12). The objective of the present study was to determine the feasibility of using field chlorophyll measurements for evaluation of corn N status.

MATERIALS AND METHODS

The experiment was conducted on Norfolk sandy loam soil (Fine-loamy, siliceous, thermic Typic Kandiudults) for two years (1990-1991) at the E.V. Smith Research Center of the Alabama Agricultural Experiment Station, Shorter, AL. The experimental sites were managed as a conventionally tilled corn production system with the goal of optimum dryland corn grain yields. Initial surface soil (0 to 15 cm) pH was 6.5 and 6.4 in 1990 and 1991, respectively. In 1990, 30 kg P ha^{-1}, 102 kg K ha^{-1}, 59 kg S ha^{-1}, 28 kg Mg ha^{-1} and 6 kg Zn ha^{-1} were preplant, broadcast applied to all plots and incorporated. In 1991, 46 kg K ha^{-1}, 56 kg S ha^{-1} and 28 kg Mg ha^{-1} were applied to all plots in the same manner as 1990. Soil P levels were in the very high range in 1991 (4), and no P was applied. Corn (Dekalb hybrid 689)[3] was planted with a John Deere Flex 71 planter[3] on April 18 and March 21 in 1990 and 1991, respectively. Row spacing was 0.91 m in both years. In both years of the study, alachlor [2-chloro-*N*-(2,6-diethylphenyl)-*N*(methoxymethyl)acetamide] (2.2 kg a.i. ha^{-1}) and atrazine [6-chloro-*N*-ethyl-*N*′-(1-methylethyl)-1,3,5-triazine-2,4-diamine] (2.2 kg a.i. ha^{-1}) were applied preemergence for weed control. Additional weed control was achieved by cultivation as needed. Although managed under dryland conditions, overhead sprinkler irrigation was applied in 1990 to prevent excessive water stress and loss of data.

The experimental design was a randomized complete block having four replications. Fertilizer N treatments were broadcast by hand as NH_4NO_3 10 to

12 d after planting to establish a range of corn chlorophyll levels, tissue N concentrations, and grain yields. Rates included 0, 56, 112, 168, 224, 280 and 336 kg N ha^{-1}. Individual plot size was 3.7 X 7.6 and 7.3 X 7.6 m in 1990 and 1991, respectively.

The V10 stage of growth (10 leaf stage) occurred 44 days after planting in 1990 and 50 days after planting in 1991. At V10, corn plants from 1 m of row in each plot were clipped at ground level for dry matter yield and N determination. Ear-leaves (20 $plot^{-1}$) were collected at midsilk (72 days after planting in 1990 and 75 days after planting in 1991) for N determination. Field chlorophyll measurements were made on the same day as V10 and midsilk corn tissue collection with a Minolta SPAD-502 Chlorophyll Meter. Chlorophyll measurements (10 $plot^{-1}$) were made on the last fully developed leaf and the ear-leaf at V10 and midsilk, respectively.

The two center rows of each plot were harvested for grain yield with a plot combine on August 28 (132 days after planting) and August 5 (137 days after planting) in 1990 and 1991, respectively. A subsample of grain was collected for moisture determination. Grain yields are reported at 155 g H_2O kg^{-1}, while all N concentration data are reported on a 0 g H_2O kg^{-1} basis.

Corn tissues were dried at 60°C and ground to pass a 0.5 mm sieve. Nitrogen in corn tissues was determined by dry combustion with a LECO CHN-600 analyzer[3].

Data were analyzed with the SAS package[3] (13). Regression procedures with stepwise elimination of nonsignificant independent variables were used. The proposed adequate linear model included linear and quadratic terms. Dummy variables (14) for year and year by other independent variable interactions were tested to determine deviations among years. Terms were eliminated from the models if they were nonsignificant at the $\alpha = 0.10$ level.

RESULTS AND DISCUSSION

A curvilinear grain yield response to N fertilization was observed in both years of the study (Fig. 2). Maximum agronomic yields were obtained with 227

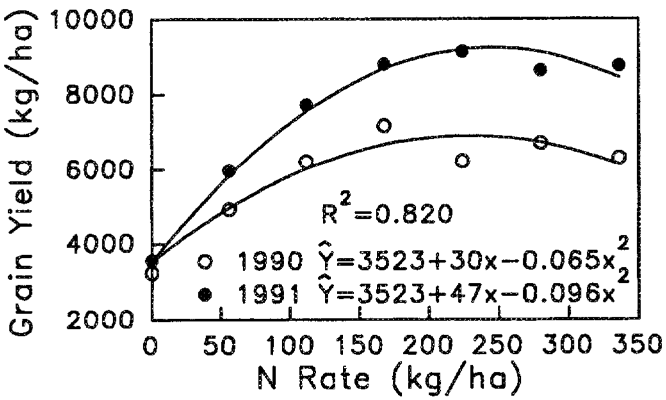

FIGURE 2. Corn Grain Yield Response to N Fertilizer at Shorter, AL during 1990 and 1991.

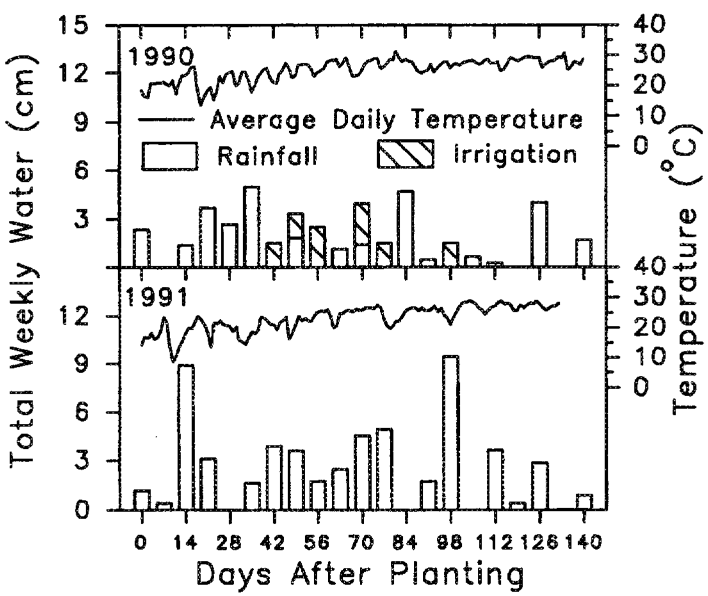

FIGURE 3. Average Daily Temperature, Weekly rainfall and Irrigation during the 1990 and 1991 Growing Seasons at Shorter, AL.

and 242 kg N ha^{-1} in 1990 and 1991, respectively. Maximum economic yields were achieved with 185 and 216 kg N ha^{-1}, respectively, in 1990 and 1991, based on a N cost of \$0.59 kg^{-1} and a grain price of \$0.106 kg^{-1}. Apparently, supplemental irrigation in 1990 was not sufficient to achieve grain yields that occurred with the high amount of rainfall in 1991 (Fig. 3). Higher grain yields in 1991 than 1990 were probably aided by the earlier 1991 planting date that resulted in a more favorable temperature regime during pollination (Fig. 3). Variation in growing season weather among years and large responses to applied N promoted conditions favorable for examination of field chlorophyll measurements (SPAD) as a tool for evaluation of corn N status.

As expected, tissue N concentration was highly correlated with corn grain yield at both the V10 and midsilk stage of growth in both years of the study (Fig. 4). Corn N status was evaluated at V10 for two reasons: (a) the V10 stage is early enough in the growing season to correct N deficiencies with side-dress N application, and (b) previous work (15) suggested that corn N status could be evaluated just as effectively at V10 as at midsilk. Midsilk ear-leaf N concentrations have been used extensively for evaluation of corn N status (16), but do not allow correction of in-season N deficiencies.

Tissue N concentrations at V10 were lower in 1991 than 1990 (Fig. 4a). Lower V10 tissue N concentrations in 1990 were due to greater V10 corn dry matter yields in 1991 than 1990 (data not shown) that diluted N taken up during early stages of 1991 growth. It was expected that inclusion of dry matter yield in combination with V10 tissue N concentration would eliminate year differences and improve the prediction of corn grain yields, however, this did not occur. Based on regression equations for V10 whole-plant N concentrations as a function of N rate (not shown), at the N rate required for maximum agronomic grain yield (227 kg N ha^{-1} in 1990 and 244 kg N ha^{-1}), V10 whole-plant tissue N concentrations were 37.3 and 30.1 g N kg^{-1}, respectively, in 1990 and 1991. The lack of agreement between years with respect to the relationship between V10 whole-plant N concentration and grain yield (Fig. 4a) suggests that this parameter

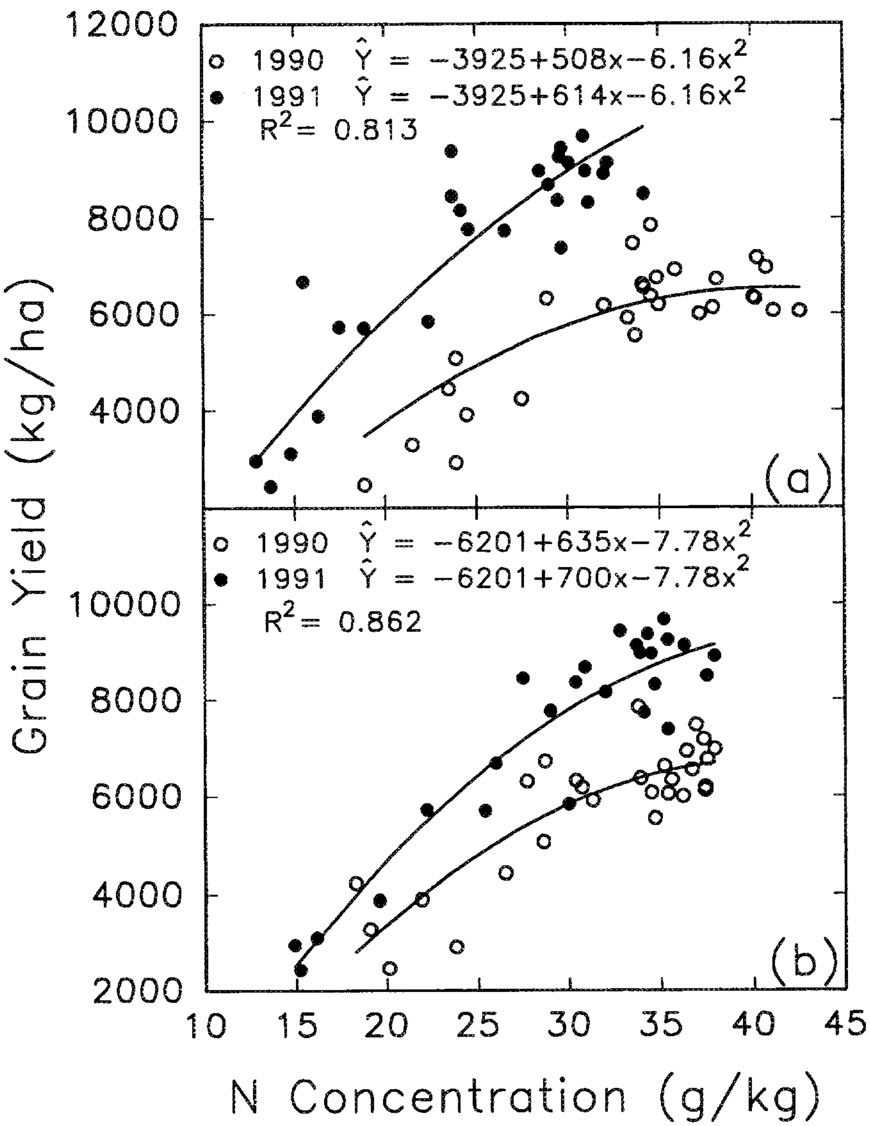

FIGURE 4. Relationship between Corn Tissue N Concentrations and Corn Grain Yields at Shorter, AL during 1990 and 1991; (a) V10 and (b) Midsilk.

may have limited value for corn N status diagnostics. A more consistent relationship (among years) between V10 N concentration and grain yield could probably be obtained by determination of N in a specific plant part, such as the last fully developed leaf. This conclusion is supported by the relationship between midsilk ear-leaf N concentrations and grain yields (Fig. 4b). Even though growing conditions and grain yields differed greatly in 1991 and 1990, ear-leaf N concentrations at N rates producing maximum agronomic yields (227 kg N ha^{-1} in 1990 and 244 kg N ha^{-1}) were similar (36.2 and 35.8 in 1990 and 1991, respectively). Our results suggest that on Norfolk sandy loam soil that maximum agronomic yields can be obtained with midsilk ear-leaf N concentrations of approximately 36 g N kg^{-1}, and that grain yield responses to N fertilization would occur below this level.

A strong curvilinear relationship existed between SPAD readings and tissue N concentrations at the V10 and midsilk stages of growth during both years of the study (Fig. 5). At V10, according to regressions, maximum SPAD readings were similar (56.0 and 54.1, respectively, in 1990 and 1991), even though tissue N concentrations were quite different among years. Field chlorophyll readings on ear-leaves at midsilk were higher in 1991 than 1990, probably due to differences in corn growth patterns, and N and carbohydrate metabolism that were promoted by different climatic conditions.

Takebe and Yoneyama (7) suggested that diagnosis of corn N status via field chlorophyll measurements may be hampered because a large portion of corn leaf N is in the NO_3-N form and is not associated with the chlorophyll molecule. Most of their studies were conducted with rice, for which little NO_3-N is found in the leaves at any stage of growth (7), and for which they found highly significant linear relationships between leaf N concentrations and SPAD readings. The relatively large curvature in Fig. 5a seemingly suggests that much of the ear-leaf N is not associated with chlorophyll, however, since the N concentrations were obtained from V10 whole-plant materials and SPAD readings were taken on individual leaves, the comparison is not entirely valid. The comparison is more

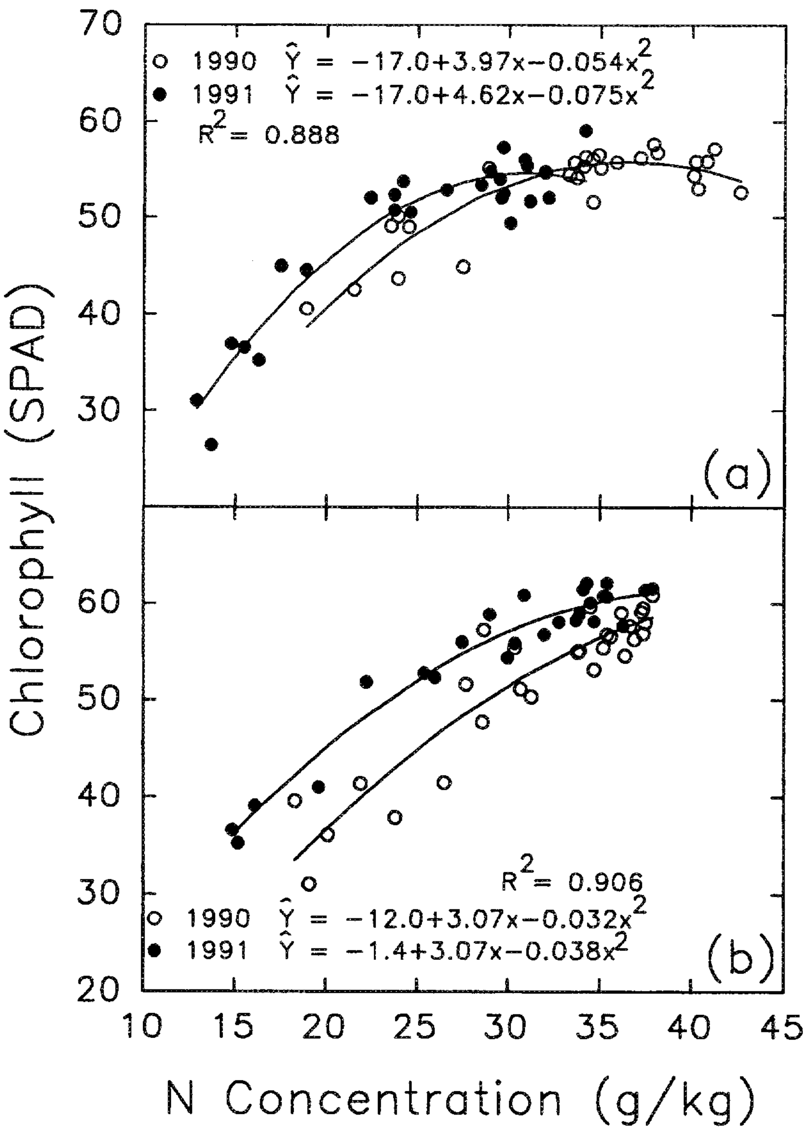

FIGURE 5. Relationship between Corn Tissue N Concentrations and Field Chlorophyll Measurements at Shorter, AL during 1990 and 1991; (a) V10 and (b) Midsilk.

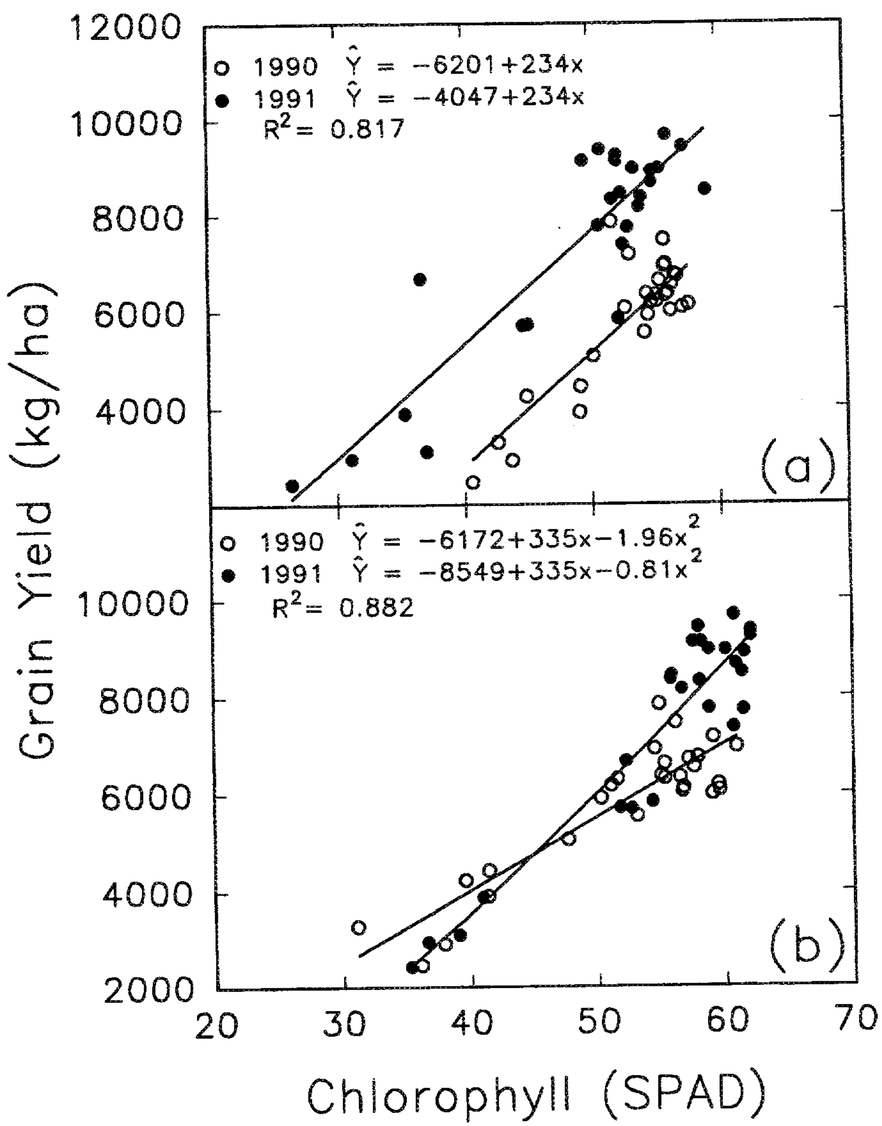

FIGURE 6. Relationship between Field Chlorophyll Measurements and Corn Grain Yields at Shorter, AL during 1990 and 1991; (a) V10 and (b) Midsilk.

valid at midsilk, where N determinations and field chlorophyll measurements were made on the same plant part. The curves in Fig. 5b are nearly linear, indicating that most of the N in corn ear leaves is associated with chlorophyll, with a lesser amount of N allocated to other forms.

Significant relationships between SPAD readings and corn grain yield were obtained in both 1990 and 1991 (Fig. 6). At maximum agronomic yield (6898 kg ha^{-1} in 1990 and 9233 kg ha^{-1} in 1991), V10 SPAD readings were 56.0 in 1990 and 56.8 in 1991 (Fig 6a). At midsilk, ear-leaf SPAD readings at maximum agronomic yield were 60.2 and 62.3 in 1990 and 1991, respectively (Fig. 6b). The similarity in SPAD readings at maximum agronomic yield among years for both the V10 and midsilk stages of growth shows promise for utilization of field chlorophyll readings in prediction of corn N status across variable climatic conditions. Especially promising are field chlorophyll measurements at V10, because supplemental N could easily be applied at that stage of growth. Our results suggest that on Norfolk sandy loam soil, that a response to supplemental N would occur at a V10 SPAD reading below 56.4. However, the design of this study did not allow for determination of the magnitude of grain yield response to supplemental N at a particular SPAD reading. Nor could this study determine the amount of N required to obtain a N response at a specific SPAD reading. More research will be required to calibrate this tool for prediction of supplemental N requirements for corn.

In summary, it appears that lightweight, nondestructive, hand-held field chlorophyll meters may have utility in prediction of corn N status. However, calibration studies are needed prior to utilization of this tool for N recommendation purposes, and we are currently conducting research that addresses this need. In addition, since corn varieties vary in tissue N status (11), studies that address field chlorophyll measurements in relation to varietal differences should be initiated.

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GENETIC NATURE OF PHOSPHORUS ACCUMULATION IN MAIZE

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ABSTRACT: The inheritance of phosphorus accumulation in the ear leaves of maize (*Zea mays* L.) was investigated. Five inbreds were chosen, two high phosphorus accumulators (Rg-8 and G-307), two low phosphorus accumulators (Rd-2 and Rg-5), and a moderate one (K-64). Their parents were used to obtain all possible ten F1 hybrids (in one direction), 10 F2, 10 B1, and 10 B2 segregational generations. Phosphorus was estimated at 50% tasseling date. Phosphorus accumulation in these genotypes was found to be genetically controlled and is affected by non - allelic gene interaction in addition to the additive and dominance gene effects. The high phosphorus accumulating inbred parents proved to be the best general combiners and the (high x low) hybrids showed the best specific combining abilities. The estimates of the minimum number of segregating genes in the (high x low) crosses revealed the presence of at least 10 segregating factors; however, the possibility of genetic linkage was not rolled out.

INTRODUCTION

Information are available that characterize some plants as high or low elemental accumulators. Sayre (18) and Gorsline et al. (9) reported that differences in elements content between inbred lines of maize are highly heritable. Neikova-Bocheva et al. (15) emphasized the importance of chromosomal and cytoplasmic effects on the uptake and accumulation of elements in plants. The uptake and accumulation of phosphorus by maize has been studied extensively by Gorsline et al. (10), Baker et al. (1), Thomas and Baker (19), Clark et al. (6), and

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